BRNO UNIVERSITY OF TECHNOLOGY

Faculty of Electrical Engineering and Communication

BACHELOR'S THESIS

Brno, 2022   Michal Pařil

BRNO UNIVERSITY OF TECHNOLOGY

VYSOKÉ UČENÍ TECHNICKÉ V BRNĚ

FACULTY OF ELECTRICAL ENGINEERING AND COMMUNICATION

FAKULTA ELEKTROTECHNIKY
A KOMUNIKAČNÍCH TECHNOLOGIÍ

DEPARTMENT OF FOREIGN LANGUAGES

ÚSTAV JAZYKŮ

SOCIAL DISTANCING TECHNOLOGIES

TECHNOLOGICKÁ ŘEŠENÍ SPOLEČENSKÉHO ODSTUPU

BACHELOR'S THESIS

BAKALÁŘSKÁ PRÁCE

AUTHOR AUTOR PRÁCE	**Michal Pařil**
SUPERVISOR VEDOUCÍ PRÁCE	**Mgr. Magdalena Šedrlová**

BRNO 2022

Bakalářská práce

bakalářský studijní obor **Angličtina v elektrotechnice a informatice**

Ústav jazyků

Student:	Michal Pařil	*ID:*	210136
Ročník:	3	*Akademický rok:*	2021/22

NÁZEV TÉMATU:

Technologická řešení společenského odstupu

POKYNY PRO VYPRACOVÁNÍ:

Cílem práce je seznámit čtenáře s aktuálně dostupnými řešeními společenského odstupu, která jsou nabízena na poli IT a komunikačních technologií.

1. Proveďte rešerši dostupné literatury na téma technologií využívaných pro zajišťování společenského odstupu mezi osobami, zejména v době pandemie nemoci Covid-19.
2. Popište vybrané technologie a kriticky zhodnoťte jejich výhody i nevýhody.
3. Výsledky prezentujte ve formě logicky uspořádaného formálního textu.

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Termín zadání: 10.2.2022   *Termín odevzdání:* 31.5.2022

Vedoucí práce: Mgr. Magdalena Šedrlová

<div align="right">

doc. PhDr. Milena Krhutová, Ph.D.
předseda oborové rady

</div>

Abstrakt

Celosvětová pandemie způsobila mnoho protiepidemických opatření. Cílem této práce bylo zhodnotit řadu dostupných technologií, které umožňují společenský odstup. Vybrané technologie byly popsány z hlediska jejich fungování a dopadu na pandemii. Zhodnoceny byly také jejich výhody a nevýhody. Ukázalo se, že všechny vybrané technologie jsou užitečné a poskytují dostatečná řešení různých problémů způsobených pandemickými opatřeními.

Klíčová slova

COVID-19, společenský odstup, drony, umělá inteligence, bezdrátové sítě, sociální média

Abstract

The global pandemic caused many social distancing restrictions. The purpose of this thesis was to evaluate a number of available technologies that enable social distancing. The chosen technologies were described in terms of how they work and their impact on the pandemic. Their advantages and disadvantages were evaluated as well. All of the chosen technologies proved to be useful and provide a sufficient solution to the various problems caused by pandemic restrictions.

Keywords

COVID-19, social distancing, drones, artificial intelligence, wireless networks, social media

Rozšířený abstrakt

Přetrvávající pandemie virové choroby COVID-19 ovlivnila celosvětovou populaci. V reakci na tento virus světové organizace a vlády představili různá opatření ve snaze zpomalit rostoucí počet nově nakažených. Tato opatření změnila běžné životy obyvatelstva po celém světě. Opatření, které mělo největší dopad je společenský odstup. Miliony lidí byly nuceny zůstat doma a vyhýbat se kontaktu s ostatními lidmi. Mnohé z moderních a dostupných technologií umožňují se v různých ohledech přiblížit k běžnému životu před pandemií.

Velké množství různých technologií bylo v průběhu pandemie použito v boji s nákazou i potížemi způsobenými opatřeními. Tato práce je rešerší, která zkoumá a popisuje různé dostupné technologie umožňující boj s pandemií; ulehčují dodržování společenského odstupu. Práce je psána ve formálním anglickém jazyce. Byl proveden výzkum vhodných zdrojů, jenž se zabývají tématy souvisejícími s pandemií koronaviru a relevantními technologiemi. Následně byl vytvořen jejich výběr. Práce je strukturována do kapitol. Každá kapitola se zabývá jednou technologií nebo menší skupinou technologií. Veškeré technologie byly zhodnoceny, a také popsány jakým způsobem přispívají k udržování společenského odstupu. Jejich výhody a nevýhody jsou také důležitým faktorem v hodnocení jejich užitečnosti.

První kapitola se zabývá bezpilotními letadly neboli drony. Drony jsou létající dálkově pilotované nebo autonomní stroje jenž slouží k distribuci zboží, monitorování, měřeni tělesné teploty nebo spreji dezinfekce. Popularita těchto strojů postupně vzrůstá a stejně tak jejich užitečnost. Technologie se rozvijí a schopnost dronů vykonávat různé úkony je efektivnější. Drony jsou schopny delšího doletu nebo unést vetší hmotnosti. Jejich přínos k společenskému odstupu spočívá v roznášení vakcín, roušek a testerů. Schopnost létat výrazně zrychluje doručovaní, dopravní zácpy nebo kvalita silniční infrastruktury nejsou omezením.

Autonomnost a pilotovaní na dálku přispívá k společenskému odstupu. Když je zboží doručováno nedochází k lidskému kontaktu. Kromě doručovaní různého menšího nákladu jsou drony schopny také monitorovat prostředí za účelem sledovaní osob. Kamery, kterými jsou drony vybaveny mohou monitorovat venkovní pohyb a případně i měřit teplotu pomocí termokamer. Drony mohou také byt použity na dezinfekci prostředí jak interiéru, tak exteriéru. Tento způsob sprejovaní snižuje riziko infekce. Hlavními

výhodami létajících dronů je jejich rychlost a velikost. Využívat drony je poměrně drahé a délka doletu určitých typů těchto strojů může být v určitých oblastech nedostatečná. Tato technologie nabízí vhodné řešení pro několik problémů způsobených společenským odstupem, ale v určitých případech je cena, dostupnost a vzdálenost doletu problémem jenž znemožňuje ji využít jako univerzální nástroj pro distribuci všeho zboží, které drony dokážou transportovat.

Udržovat společenský odstup při nakupování pomáhá skupina technologií popsaná v druhé kapitole. Je možné regulovat počet zákazníků i zaměstnanců. S pomocí samoobslužných pokladen lze snížit množství zaměstnanců; pouze jeden pracovník je schopen dohlížet na několik pokladen tohoto typu. Pokud je v obchodě několik těchto pokladen, dochází k tvorbě menších front. Ve frontách je vyšší šance nákazy. Samoobslužné pokladny jsou dražší, ale okupují méně prostoru a setří zaměstnance.

Digitální peněženka je software nebo zařízení uchovávající data uživatele pro potřeby placení online nebo v kamenné prodejně. Placení pomocí digitální peněženky je při pandemii bezpečnější a hygieničtější.

Sociální média v době protipandemických opatření mají klíčovou roli v komunikaci. Je možné být ve spojení s kýmkoliv na světě; sociální média používají v době protipandemických opatření jak běžní jednotlivci, tak i profesionálové ve zdravotnictví pro sdílení důležitých informací. Popularita sociálních medii vzrostla v době pandemie. 57,6 % světové populace používá sociální media a počet uživatelů stále roste. Tato technologie pomáhá po celém světě lidem komunikovat a sdílet své osobní problémy s pandemií. Velkým rizikem je šíření falešných zpráv, které může vést k nežádoucím reakcím.

Bezdrátové technologie jsou užitečné pro monitorování pohybu osob v interiérech i exteriérech. S pomocí Wi-Fi lze s určitou nepřesností sledovat počet osob ve veřejných budovách. Pokud protipandemická opatření přikazují omezený počet osob v budově, počet osob je omezen metry čtverečními, lze pomocí Wi-Fi měřit počet návštěvníků za předpokladu, že každý z nich se připojí pouze jedním zařízením. Mobilní sítě a globální družicový polohový systém (GNSS) jsou bezdrátové technologie s jejichž pomocí lze sledovat osoby s přijímačem. Tento způsob sledovaní lze aplikovat na osoby jenž mají být v karanténě. Narozdíl od Wi-Fi, GNSS disponuje téměř globálním pokrytím umožňující rozsáhlé sledování s přesností na 2 metry.

Umělá inteligence (AI) je simulace lidské inteligence zpracovaná počítací. Tato technologie není v současné době dostatečně vyvinutá a efektivní použiti. Z provedených testů je dokázáno, že může potenciálně sloužit k měření vzdálenosti mezi lidmi ze záběrů bezpečnostních kamer a kontrolovat dodržování společenského i fyzického odstupu. Existence různých algoritmů a strojového učení pomáhá z data nahraných bezpečnostními kamery nebo i v reálném case rozpoznávat chodce a identifikovat, zda dodržují fyzický odstup.

Veškeré popsané technologie v této práci určitým způsobem přispívali lidem vyrovnat se s následky protiepidemických opatření. Dodržovaní společenského i fyzického odstupu je v mnoha situacích velmi obtížné. Technologie jako drony nebo umělá inteligence potřebují ještě další vývoj v dosazeni dostatečné efektivity. Mnohé současné technologie celkově nabízí funkční a dostatečně efektivní řešení pro společenský odstup.

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Prohlášení autora o původnosti díla

Jméno a příjmení studenta:	*Michal Pařil*
VUT ID studenta:	*210136*
Typ práce:	*Bakalářská práce*
Akademický rok:	*2021/22*
Téma závěrečné práce:	*Technologická řešení společenského odstupu*

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V Brně dne: 31.5.2022   ---------------------------------------

                                                 podpis autora

Poděkování

Děkuji vedoucí mé semestrální práce Mgr. Magdaleně Šedrlové za účinnou pedagogickou a odbornou pomoc a další rady při zpracování mé bakalářské práce.

V Brně dne: ---------------------------------------
                                               podpis autora

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INTRODUCTION

The global pandemic has significantly altered living conditions all around the world. This caused many restrictions which in turn encouraged inventive applications of already available technologies. Social distancing is one of the most impactful restrictions, influencing how the whole world operates. The entire world was forced to accelerate its transition to online spaces in order to stay operational. Social distancing caused by the virus put the most reliance on technology in modern history. The social distancing guidelines that were introduced by governments rapidly shut down many businesses and those who could not adapt fast enough never recovered. Fortunately, many of the current technologies allow people to communicate, work and even socialize in those dismal times. These technologies are changing and developing rather quickly, therefore allowing for less personal contact than ever before.

Social distancing also influences people on a psychological level; communication on social media is convenient but it cannot legitimately replace personal human contact. Social distancing brings the dangers of increasing impersonality, individualism and the loss of a sense of community. Such dangers give technologies, the opportunity to positively influence and create a pleasant environment for individuals to live, work or socialize in.

There are two widely used terms referring to distance maintaining. The term social distancing applies to staying at home and away from others as much as is possible, whereas physical distancing means keeping distance between people. The designated distance among individuals is around 2 meters or 6 feet.

Many technologies were deployed to help during a pandemic. Adoption of these new technologies has become widespread. A number of wireless technologies previously used mainly for communication or navigation can additionally serve as an applicable solution for maintaining social distance. Drones manage the distribution of medicine, masks or tests. A number of various applications are utilized for communication and the popularity of contacting online increased immensely due to pandemics. News portals and social media provide convenient access to quickly spreading information that may not always be trustworthy. When technologies work together, they usually produce pleasant results helping people ease their lives. This thesis describes and evaluates certain technologies that are used for social distancing during pandemic restrictions.

1. DRONES

A drone is an Unmanned Aerial Vehicle (UAV), ergo a flying machine with the ability to fly a pre-set course on an autopilot using Global Positioning System (GPS) coordinates or be remotely and manually piloted via radio controls by a person, proving quite useful in a global pandemic. Drones can be piloted or be autonomous; they could be navigated by a pilot with a transmitter or without the flier and be completely autonomous using GPS. The term UAV can also refer to an entire system. Such system includes additional communication with the drone and remote controller that is located on the surface. In certain dangerous situations it can be safer to have the drone manually controlled. UAVs allow for safer environment due to their ability to fly long hours without the human fatigue in the plane. They can fly as far as the vehicle allows for without any qualified pilot. According to the article Application of Drone in Agriculture written by Ahirwar et al. (2019) certain drones are capable of staying in the air up to 30 hours and not being disturbed by the time of day or fog is a substantial advantage. Potential drone pilots can conveniently hand over the drone's controls back to the software without any loss of time or effectivity, maintaining their high accuracy. Smaller vehicles frequently have four fixed propellers that are oriented vertically and are powered by lithium-polymer batteries. Certain larger drones are powered by fuel cells. According to the book Fuel Cell Systems written by Blomen and Mugerwa (2013, p. 37), the fuel cell is "an electrochemical device that is used to convert the free-energy change of an electrochemical reaction into electrical energy".

Drones can be divided into groups based on the method they use to fly. Fixed-wing vehicles use regular wings like planes allowing to them to fly over longer distances. Multi-rotor drones are cheaper, can cover smaller distances but their main advantage is vertical lift-off and ability to hover. This type of flying vehicle with four rotors is called quadcopter. The propellers heavily effect the drone's manoeuvrability, speed and the weight of carriable cargo. According to the article by Ahirwar et al. the longer the propellers are the greater lift can be accomplished. The length of propellers controls acceleration as well. Long propellers change speed less effectively than short ones. Whereas short propellers are able to manoeuvre faster but require higher rotational speed to remain in the air. The speed of each propeller is controlled by a motor speed controller

that sends controlled current to achieve desired spin speed and direction. Motors are attached to a chassis which must be as light as possible while durable enough to hold all internal or attached components together. Unnecessary weight requires stronger propellers and more power to be flown. The most common materials used for drones are carbon fibre composites which are lightweight due to their density.

In a global pandemic, various innovative attempts were made to employ drones to help in various scenarios. This technology is at the point that it can feasibly affect medical distribution to different kinds of success. Drones can be very useful in aerial spraying, sample pickups, delivery of goods and space monitoring. Being deployed all around the world, this technology's help proved itself to be adaptable to almost every environment. According to the article by Skorup and Haaland (2020), "some African countries invited a number of American companies to assist in their rural hospitals." The country that uses drones the most to battle COVID-19 is China. They were, for example, used to transport medical equipment in Wuhan such as face masks or testing kits. The deployment of these vehicles is not limited just to certain African regions, they were utilized in many countries, especially those that are technologically advanced. Launching drones directly from hospitals saves a lot of time. Drones are faster than regular road transportation, they do not need roads to get around or bridges to travel across rivers, cutting down travel time significantly. Being remotely controlled makes the chance of spreading the virus definitely lower and continues the trend of taking humans from places where they are not critically necessary.

1.1 Aerial spraying

Disinfection of public spaces can significantly help to prevent the virus from spreading. Attempts to use drones as disinfection carriers occurred in China, South Korea and Spain. Ordinary disinfection equipment is heavy and difficult to carry, whereas flying drone is more capable of overcoming obstacles. According to González et al. (2021), an operational study on drone spraying application done by a team from University of Vigo, the drones can have the capacity to carry up to 5.5 L. "These drones have a maximum take-off weight of 14 kg. In 7 min such drones are capable of covering an area of 20.000 m^2 while using a brushless pump". This procedure can be applied to a place where other methods would be too costly, expensive or slow. While spraying, the drones can use a

Global Navigation Satellite System (GNSS) or be remotely controlled. GNSS allows for planning of the path they must take in order to evenly and effectively spread disinfection. Outdoor areas such as skate parks that are exposed to the elements can affect drones work, whereas in indoor areas such as gyms drones can work unharmed and unaffected. In these situations, drones can prove quite effective.

1.2 Space monitoring

Due to their cameras, size and mobility, drones can be deployed in public spaces as surveillance devices. Obtaining much better situational awareness is for governments crucial as they are trying to force people to obey restrictions that they had implemented. It is also possible to broadcast messages over loudspeakers. Drones can track people with regular cameras and with the equipment of thermal cameras the temperature of pedestrians can be measured, tracing those who are potentially dangerous. While this use is important and potentially lifesaving, it can also eventually lead to the abuse of civil rights. People being monitored constantly puts unnecessary pressure on everyone in times when everyone is already tense from continually changing regulations.

1.3 Delivery of goods and medicine

The use of unmanned aerial vehicles expanded to various tasks such as delivery of goods and medicines. These tasks include delivery of tests, vaccines and other supplies that might be needed in areas with dangerous weather condition, barren transportation networks or heavy traffic congestion. Areas that were recently hit by natural disasters can benefit heavily from using drones for delivery. Such areas have damaged infrastructure and acute need for medical supplies that should be delivered as quickly as it is possible. Drones are still a new method of transportation and if used for medicines that can save lives they should be thoroughly tested worldwide.

The study An Evaluation of the Delivery of Medicines Using Drones written by Hii et al. (2019) states that the Californian company Matternet provided their services to deliver medication to camps in Haiti after serious earthquakes and to secluded areas in Switzerland, Dominican Republic and Bhutan utilising drones with the capacity to carry up to 2 kg of equipment. Application of drones in this situation is similar to how drones were deployed to deliver goods during the COVID-19 pandemic.

1.4 Optical and thermal cameras

Hardware that drones are equipped with allows for an accurate data collection. Different cameras can be used for acquiring information related to coronavirus detection and face recognition.

Thermal cameras capture images using infrared radiation. Infrared data are then converted into an image that differentiates temperatures of objects by colours. Images from thermal cameras are often monochromatic.

Since thermal cameras provide information about temperature and captures coloured images (Mohammed et al., 2020), its benefits for recognition of potential infected people are significant. The data collected from optical and thermal cameras can help in detection of individuals who show higher body temperature, thus being potentially infected with COVID-19. Drones are able to livestream video back to the drone pilot. This system detects crowds including temperatures of people attending them. The procedure is useful in measurements of social distancing and density-based thermal imagining (Kumar et al., 2020).

Figure 1.1

The difference in body temperature
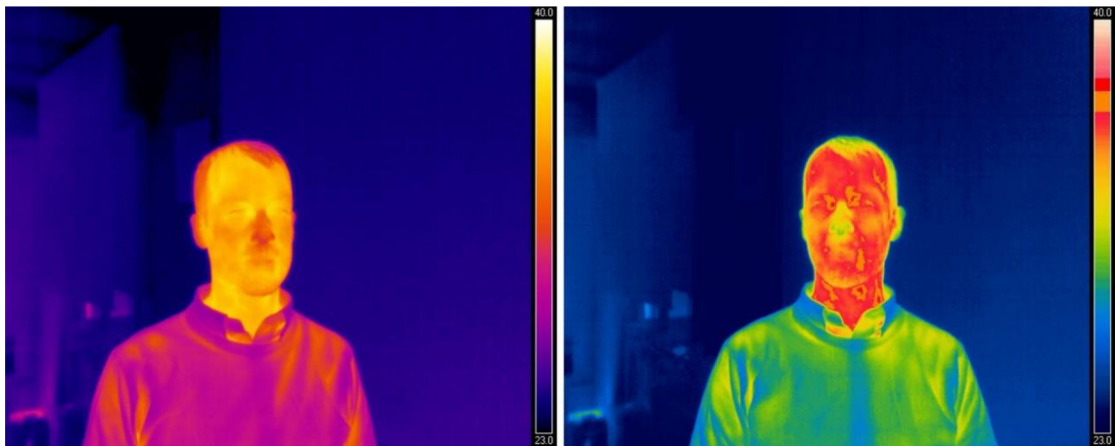
Note. High body temperature or fever can be quickly detected by thermal imaging cameras. The colour red distinctly demonstrates increased temperature; a symptom of COVID-19 (de Griñó, 2020).

2. TECHNOLOGICAL SOLUTIONS OF SHOPPING

Economies are greatly affected during a worldwide pandemic. COVID-19 restrictions have significantly changed how businesses operate, pushing them to rely much more on online sales and advertisement. Some countries deployed measures so severe that some businesses were forced to shut down completely. Shutting down businesses leads to unemployment that affects the economy. Many businesses were forced to adapt in order to sustain their profitability and started offering new services such as the option to deliver goods directly to customers' doorstep. Online advertising has become quite a necessary method of growing or maintaining business and attracting new customers.

Due to the availability of internet connection customers are instantly informed on new products and services. New technologies are constantly being developed and deployed to enhance or streamline the shopping experience for customers and shop owners as well. These technologies can offer safer, faster and better shopping. The deployment of smart technologies online and in stores can affect human contact, since the more automated a process is, the fewer employees are simultaneously required on a shift and thus reducing potential infection.

2.1 Self-checkout technology

Self-checkout refers to the process of paying in retail by oneself usually partially assisted by smart technology and thus minimizing contact between customers and staff, not only during COVID-19. Nowadays, some people prefer to interact with machines rather than with other people. Self-checkout does not require the customer to talk to anyone and preserves anonymity while purchasing almost any type of product. Self-checkout machines or kiosks that allow for paying and sometimes ordering can prevent queues since customers divide into smaller groups thus creating shorter queues. According to a survey by Box Technologies and Intel (2020) "90% of UK shoppers actively avoid shops with long queues". Installation of these terminals in retail leaves customers to check out their goods at their own pace.

Disinfection is an important factor in a global pandemic. Self-checkout machines should be sanitized often since their touch screens are used by every customer. A significant advantage of the terminals is that they do not require as much space as regular

tills. One regular till can be replaced with a number of automated self-checkout machines. Additionally, less staff is necessary to operate automated terminals and therefore ordered elsewhere since a number of the machines can be monitored by one staff member and cameras provide uninterrupted monitoring. Intelligent camera systems can recognize what items are being scanned and detect if a customer is trying pass a product as something else. If customers need help or try to steal a staff member is there watching. According to an article by Pezzini (2020) on LS Retail, machines that handle cash are generally more expensive than those that do not but the number of cash payments is slowly decreasing resulting in the most cost-effective solution being the combination of card only terminals with regular manned tills.

2.2 Digital wallet

A digital wallet is a software or device that securely stores a user's data such as payment methods, websites and information. This type of wallet is the primary interface for transactions with cryptocurrencies. Saving money digitally is comfortable because digital wallets serve as a convenient tool for online shopping. Easily providing shopping information online is effective, fast and flexible. Banking apps such as PayPal can be installed on smartphones turning them into digital wallets. Paying via a digital wallet or mobile phone is fast, convenient and more hygienic than cash but these payment methods are not accepted everywhere.

2.3 App-based shopping by appointment

Appointment shopping is when shoppers use timeslots to book a shop visit. When a shop has restrictions regarding the number of customers inside, a site or app-based appointment system can help shop owners and shoppers allowing them to have a comprehensive schedule. Through this online system, customers can book an available time slot that suits them. The process for booking should be effortless since shoppers might get easily discouraged if it seems too complicated. Shops that are usually busy have problems with keeping the social distancing restrictions. Appointments done through an app or site let customers freely explore the entire shop without worrying about restrictions, especially for shops that rely heavily on personal interactions with their shoppers. It is an easy way to regulate the number of customers and manage employees.

Some people are not comfortable surrounded by individuals that pose a threat to them. According to the data from Future of Retail Report by Shopify (Ambrose, 2021), "50% of customers find the option to schedule a time slot for personal shopping relevant to them". The fewer people occupy the store the more are the employees capable of managing safety. Personal interactions lead to a better customer experience. Due to the use of this system employees can sanitize surfaces and other items that have been touched by shoppers.

According to Ambrose (2021) there are many options of software that can be used for appointment scheduling and it is important to collect feedback from customers. Shops could have custom software developed or use one of the already available digital solutions. The customer should get a seamless and effortless experience from using the app or site. The service should be fast and responsive to help improve customer experience. This solution covers business-to-business (B2B) meetings as well. App-based appointments provide a sufficient solution for shopping or business meetings during pandemic restrictions due to their accessibility, fast implementation and opportunity to manage customers personal shopping experience.

3. SOCIAL MEDIA

Social media allow for a fast dispersal of information and is an immensely vast place for billions of people to communicate, socialize and join online communities. Social media sites allow individuals to interact from anywhere and anytime. People share, post and send messages of their everyday lives, affecting how individuals interact online and creating new ways for discussions. Social media sites are constantly evolving and adapting to new trends and technologies. These include the development of more powerful mobile phones and computers, better availability of internet connection and advancements in software tools development. Increase in affordability of mobile devices and internet connection play a big role in social media interest. Analysis by Kepios shows that 57.6% of the total global population use social media.

Access to new and reliable information during a pandemic is crucial but people should be careful while they are reading. The information on social media can greatly change people's opinions and behaviour. Governments can use platforms such as social media to spread warnings and news regarding restrictions. The ability to communicate with anyone over the internet under social distancing regulations is valuable and sometimes the only viable option. During a lockdown social media are also used by medical professionals to communicate with each other and their patients as well. This technology has an enormous impact on information accessibility. Scientists from different medical fields and areas are able to share their findings and research procedures. Allowing for fast responses or actions.

According to Cinelli et al. (2020) social media use algorithms that monitor users' preferences and promote specific content based on collected data. This can lead to the spread of misinformation. Misinformation or 'fake news' is inherently false but it is shared without intent to cause harm. Rumours and misinformation posts that are presented the same way the reliable posts would be. It is difficult to distinguish them and some people are not willing to verify untrustworthy information. Some individuals tend to receive information from polarized groups that adheres to their twisted perspectives. Ignoring other reliable sources, they spread the misinformation further. According to Wang et al. (2021) misreports spread easily and reach many people. Some studies determined that misinformation can be shared and spread faster than credible news,

especially on Twitter. Since people relied heavily on social media during lockdowns and participated in many political debates, rumours spread easily. People tend to form social perceptions and frame narratives while online. According to an article on Journal of Clinical Epidemiology (JCE) by Cuello-Garcia, Pérez-Gaxiola and van Amelsvoort (2020) more than half of social media users have encountered some information regarding the COVID-19 pandemic they considered erroneous. Researches on social media focus on detecting misinformation sources while constantly trying to improve their methods. As stated in "The spread of true and false news online" published in the journal Science written by Vosoughi et al. (2018), deceptive sources should be counteracted as fast as possible to prevent fake news spreads. "False news can drive the misallocation of resources during disasters".

Social media are a wide spread platform for news and communication with some necessary regulations to prevent unwanted outcomes, especially during a pandemic when misinformation can cause serious difficulties. When communication is difficult due to a variety of COVID-19 restrictions, social media provide the easiest and most accessible option to communicate.

4. WI-FI

Wi-Fi is a wireless technology that is used to connect devices to the internet. Various wireless technologies can be utilised to enable social distancing. Wi-Fi technology is widely used all over the world. Being primarily used indoors creates a reliable solution since satellite technologies are not as accurate as Wi-Fi in indoor settings. Places such as shopping centres, airports, train stations, libraries and office buildings are commonly equipped with Wi-Fi connection, making it a convenient solution. The most expedient application of this wireless technology under social distancing restrictions is in indoor environments.

4.1 Crowd tracking and detection

Social distancing positioning is a viable application to be used by authorities and governments due to its cost, usage and reliability. Users' position can be tracked making easier to detect how people move and if they are following social distancing rules. Authorities can detect crowds and force them to keep safe distances. This is useful for social distancing practise. Wi-Fi can provide location based on Received Signal Strength Indication (RSSI). It is a measurement that determines if a device has enough signal to get a good wireless connection. The accuracy of this solution further depends on the applied propagation model. According to A Comprehensive Survey of Enabling and Emerging Technologies for Social Distancing – Part I: Fundamentals and Enabling Technologies written by Nguyen et al. (2021) the simplest method to detect a user's location is by calculation based on the RSSI of the received signals from the user device. The most accurate method is realized by using real-time calculation. The method is realized by continuously determining RSSI values in real-time. The distance between the user and access point is precisely calculated.

4.2 Monitoring indoors

Controlling the number of individuals in a building such a library, school, and gym can be done via a Wi-Fi technology using a collection of routers serving as access points. The number of connections from user devices can be computed resulting in an estimate number of visitors. The more area is covered the more accurate the result is. The outcome

is useful because the fewer visitors there are, the lower social contact there is and lower chance of virus spread. Authorities might use these data to monitor situation precisely or force people to leave. If the building is at its limit potential, visitors could be forced to leave and allowed to come inside when the building is less occupied. A disadvantage of this method is that not all individuals carry around a smart device. Networks are limited by how many devices can be simultaneously connected. The Wi-Fi coverage of the buildings area partially affects how many people will opt for cellular connections; some individuals rely on cellular connection completely when not at home. This method is applicable to any building that cannot easily monitor the number of visitors and operate a number of access points. It could be a reliable help in maintaining COVID-19 restrictions in frequently visited indoors environments.

5. CELLULAR NETWORKS

Cellular networks allow for position monitoring in real-time. Due to their growth in recent years, these networks became the primary way of communication for many people. The popularity and spread of this technology can be used for crowd density monitoring or to encourage people to stay at home during a lockdown. The use for social distancing user movement history can be quite effective. People who are in self-isolating quarantine or infected could be tracked by authorities who are monitoring the movement. The disobeying individuals might be sent warning messages. The user's movement history is also saved. When someone is infected or exposed to the virus their history can be examined to prevent unnecessary spread. The previous mobility data also show all potential infection candidates allowing for additional measures. Since cellular technology is widespread beating other wireless technologies in terms of use.

According to the article Coronavirus: Under surveillance and confined at home in Taiwan on BBC (2020), the Taiwanese government required telecom companies to share their mobile phone location data to help maintain COVID-19 restrictions. The government use phone-tracking system to monitor the position of the owner and occasional calls ensure whether the owner has their phone at hand. A mobile phone can be turned off or left at home when outside. For example, when a connection is lost the local authorities might dispatch a patrol to check one's whereabouts.

Every position tracking technology leads to concern in people since their privacy is being breached. There is a different method that is less invasive. According to Nguyen et al. (2021) the crowd detection solution is monitoring based on anonymous location data that is being collected from users. This method is less invasive maintaining more privacy and simultaneously helping with pandemic restriction heeding. It additionally helps with the creation of models that represent the spread of COVID-19. These models are used to evaluate and analyse how effective the deployed quarantine measures are in practice. These data can be used for people density prediction. The data collected from users in specific areas that are being tracked can predict traffic and crowd gatherings allowing for appropriate actions from authorities. The technology can serve in residential areas to monitor when people stay home or leave. This helps significantly with additional predictions in traffic.

5.1 Working and studying from home

In a lockdown, many people work, study and perform their daily ordinary activities from home leading to a significant boost in use of communication applications. The 5G technology could be very useful for the purpose of encouraging people to stay at home. In places where landline internet is not accessible 5G provides an alternative and simple solution. The user experience of many applications is crucially improved by advances in cellular networks therefore video broadcasting in high definition is not a difficult task. Working or studying at home is thus quite convenient and there is less need to leave home. Fast and stable internet connection at home creates a pleasant environment for working. The possibility to get everything done from the comfort of home increases social distancing.

Figure 5.1

Cellular reception covers an increasing percentage of the world's landmass every year

Note. The growing reach of networks provides increasing quality of data. Tracking hardware can be potentially monitored in more than 170 countries (Cellular Tracking Technologies).

6. GLOBAL NAVIGATION SATELLITE SYSTEMS

The satellite navigation system technology (GNSS) is widely spread due to its global coverage. Being commonly used outdoors for positioning purposes makes it a compelling choice for pandemic applications. GNSS technology operates via usage of satellites that orbit the Earth while constantly broadcasting messages used for navigation. Devices that operate with these messages to calculate their own location. According to Nguyen et al. (2021) the location is computed from the time that it takes to transmit a message from the position of the satellites to a user's device. At least three satellites are necessary since three messages from each orbiting satellite are required to compute the current location of a device, resulting in high positioning accuracy and proving itself as a suitable solution for social distancing, especially in outdoor environments. GPS is one of the types of Global Navigation Satellite System. Almost every smartphone is equipped with GPS technology allowing for tracking. During a pandemic, people who are supposed to be in isolation due to infection or contact with an infected person can be monitored when necessary. These people can wear devices utilizing GPS that send data to the authorities.

6.1 Movement tracking

A significant advantage over Wi-Fi is the ability to track anywhere due to its wide accessibility and worldwide coverage. Wi-Fi is generally limited to buildings and areas whereas GNSS is not limited in such way. The satellite navigation system is capable of positioning down to 1 m. GNSS is more useful and accurate outdoors but Wi-Fi is more precise indoors. In crowded areas services based on GPS might have decreased accuracy due to possible interference signals. GPS operates on smartphones or specialized devices that can be wearable or a part of a larger machine (e.g., car, ship or drone). Live GPS tracking on smartphones is possible via an app that is supervised by a service provider determining whether or not the user is maintaining restrictions (Nguyen et al., 2021).

Privacy is a key factor in resolving the effectiveness of this technology because identity protection is important. In outdoor environments, GNSS is quite an acceptable solution for tracking. Smartphones are widely available and utilized in everyday lives and their features allow tracking to be simple. GPS additionally calculates movement

patterns and a person's mobility history serves as a tool assisting the cause against COVID-19. People have to wear a device or turn on an app on their mobile phones to allow positioning to keep track of them. In general, services based on GNSS have many advantages such as group monitoring, user tracking, keeping distance and worldwide coverage (Nguyen et al., 2021). This technology is rather expensive and not utilized by every public service. Privacy is breached since users are being watched rather closely.

GPS accuracy is not precise enough for distances lower than two meters, causing difficulties indoors, especially in crowded areas, and leaving room for additional improvement. GNSS is sufficient enough to help combat the COVID-19 pandemic but lacks accuracy in certain areas and not everyone is willing to have their privacy breached. In combination with Wi-Fi, these technologies provide an effective position tracking solution that is usable for monitoring maintaining restrictions with the disadvantage of the breach of privacy, occasional inaccuracies and higher cost.

7. ARTIFICIAL INTELLIGENCE

Artificial intelligence (AI) is a simulation of human intelligence that is processed by computers. The article What is artificial intelligence? on SearchEnterpriseAI written by Burns et al. (2021) states that artificial intelligence systems work by "processing enormous amounts of labelled training data". These data are analysed for patterns or correlations. These patterns are then used for predictions of future states. AI systems serve as a tracking and monitoring tool to help maintain social distancing in real-time. A tool that tracks cars, people and bikes anonymously and can help governments monitor how restrictions are maintained. AI sensors networks provide streams of data on city transport. For example, in 2020, Vivacity, a company based in London, used sensors across parks, residential zones, retail zones and canals in various UK cities. To demonstrate how capable their solution could be, they detected that "only 54% of pedestrians followed the 2m guidance" (Catapult, 2020). AI deals with many aspects of computer science. During a pandemic, it can serve to help in the medical sector as well. For example, according to the study by Ting et al. (2017) AI can classify skin cancer or identify diabetic retinopathy using retinal images. This allows for less human contact since the evaluation is done quicker and remotely supporting social distancing restrictions. An image is taken via the use of digital photography and then is evaluated by a trained AI.

While artificial intelligence is constantly improving it still needs a lot of testing. With advantages such as having consistent results, reduction of human error and being fast in detail-oriented tasks it still has downsides. AI is expensive since it requires state of the art software and hardware. Using AI to replace repetitive minimum qualified jobs can lead to unemployment and laziness.

7.1 Machine learning

Machine learning is a part of artificial intelligence and the study of algorithms. It is a sub-field of AI and is utilized in a wide variety of applications. The benefits of this technology help maintain COVID-19 restrictions in various scenarios. According to IBM (2020) machine learning "focuses on the use of data and algorithms to imitate the way that humans learn". This learning method allows for a continuous improvement in accuracy. These training data are used to improve algorithms, the more data an algorithm uses the more accurate its predictions may become.

Deep learning is a method and branch of machine learning. The main difference between machine and deep learning is how these branches of AI learn. Deep learning according to IBM (2020) "automates much of the feature extraction piece of the process, eliminating some of the manual human intervention". Deep learning algorithms are still being developed and continuously improving.

According to Rahim et al. (2021) the modern research field is interested in deep learning techniques. YOLO (You Only Look Once) v4 is an object detection algorithm that was released in 2020 by Alexey et al. and improves on flaws of its previous versions. Its main improvements are in speed and accuracy of object detection, each version is more effective than the previous one.

The architecture of YOLO is comprised of three major parts: backbone, head and neck. According Rajput (2021) the backbone is a type of architecture that "basically acts as a feature extractor. All of the backbone models are basically classification models". Features are essentially parts of an object in an image. These parts might be corners or edges that are used to help identify objects. Backbone additionally features a GPU (graphics processing unit). Neck functions as a feature aggregator and head "finds the region where the object might be present but doesn't tell about which object is present in that region" (Rajput, 2021). Feature aggregation is a method that combines features from different datasets to learn relations between them. Aggregated features summarize a number of simpler or low-level features.

YOLO is suitable for detection of people in a wide variety of light conditions. Rahim et al. in their work tested the effectivity of the YOLO algorithm on various image takes at differently lit environments from the Rawalpindi market in Pakistan. These images were taken during the COVID-19 pandemic. Rawalpindi being one of the most populated cities, social distancing in such conditions is a difficult task to achieve. The more populated areas are, the more challenging it is to maintain restrictions, thus surveillance systems in these environments should feature high accuracy.

Rahim et al. (2021) in their research chose 346 frames taken with Samsung galaxy note 10+ to evaluate the effectivity of the YOLO v4 algorithm. In low light environments the model showed favourable results since no false positives were detected and very few false-negatives. For example, the people who violate social distancing of a distance 100 cm, could be highlighted by red bounding boxes in the processed frames.

This research demonstrates the capabilities of the algorithm and shows its potential. The application of the use of YOLO v4 on real-time video feed still has its limitations. A camera equipped with a ToF (Time-of-Flight) sensor is required. These devices are capable of depth determination utilizing infrared light that is not visible to the human eye. The time it takes the light to travel from the camera to an object and back is measured and distance then computed. Additionally, to correctly apply the algorithm and compute distances among individuals, two temporary target objects must be place in the environment (Rahim et al., 2021). These target objects must be placed at the designated distance in order to ensure correct calculations and mapping of pixels to real world units.

Since the YOLO v4 algorithm holds high precision its application in distinct light conditions in real environments is possible and provides a solution for social distancing monitoring even in densely populated areas. Different camera hights and angles might offer additional challenges and opportunities for further testing. Cameras using deep learning algorithms could provide monitoring in outdoor and indoor areas. In their research Rahim et al. (2021) proved that even in low light conditions YOLO is still sufficient in accurate monitoring.

Figure 7.1

A red box highlights people coming closer by less than 5-6 feet

Note. Crowds can be tracked in real-time via CCTVs. People who come closer together than 5 – 6 have a red box drawn on them (Banerjee, 2020).

8. VIRTUAL SOLUTIONS

Social distancing restrictions pose new challenges and opportunities for training programs. It is crucial for students and trainees to continue work in their respective study programs. Medical students are of special importance. Training programs should provide realistic and useful experiences that are applicable to real situations. COVID-19 restrictions make it difficult to run these programs and initiate any kind of in person interview or get experience. Modern technologies offer various solutions to these problems.

8.1 Technologies used for virtual tours

Restrictions cause many complications in travelling and distributions. Virtual tours or visits may help to overcome some of these difficulties. Saving time and money is a long-term goal that technologies utilized for virtual visits might help achieve. This kind of application is not new since the real estate industry has been using virtual visits for years and the healthcare industry similar technology adopted as well. Virtual tours vary depending on used technologies. Different kinds of digital reality are used in virtual tours. Both augmented and virtual reality can be utilized when creating a virtual tour experience. Interiors can be filmed in 360 degrees, enabling viewers to look around and observe the location as closely as the quality of the video allows. A sequence of pictures or videos also might suffice. For example, YouTube supports the 360 degrees video format. Digitally recreating immersive environments serves as a great alternative to traditional visits. This way, viewers are able to experience the digital surroundings as closely as possible without actually being there. Not only virtual tours help students, they additionally keep tourism active to a certain degree.

During a pandemic virtual tours became an important method of obtaining income for businesses relying on tourism. For medical students, it is of high importance to see and experience as much as they can during their studies. Virtual tours, web interviews, videos and virtual reality can make a significant difference. Some companies started to invest more into their virtual platforms due to higher demand for virtual tours, since COVID-19 changed people's ability to travel. Growing popularity of VR supports this transition to virtual spaces. These tours can be used as marketing tool for services or products. When

the cost of a service is high, the option to virtually try it before purchase is quite convenient. Visiting places from the comfort of one's home is a comfortable and cost-effective solution. For example, certain airlines allow their customers to view the interior of their aircrafts prior to the purchase of a ticket. During a pandemic, when it is more complicated to arrange trips to vacation destinations that closed due to the risk of infection, the alternative way of visiting might offer a good preview and make people think twice before deciding whether it is worth the trouble. These virtual tours also include visiting places of the past. Computer generated projections with the expertise of historians allow for experiences that are not possible in real life anymore. With virtual tours there is no need for actors who are forced to perform in historical re-enactments. Technologies enabling these tours also make it possible to virtually visit normally inaccessible places. Places that are off-limits for various reasons, whether it is due to COVID-19 restrictions or not.

8.2 Virtual and augmented reality

Environments simulated and generated in a computer have come a long way. Virtual reality (VR) is able to create immersive environments that appear believable or at least to a certain degree. VR is experiencing a virtual simulated world through screen of a headset. The large difference between 360-degree video and virtual reality is the interactivity. Watching a 360-degree video is a passive experience where viewers cannot interact with anything whereas virtual reality allows for unprecedented levels of interactivity. VR is dynamic and most importantly adapts to what the user is doing. 360-degree video is not as immersive as virtual or augmented reality.

Augmented reality (AR) is an experience where real environment is enhanced by digital visual elements, sound and haptic feedback. It is a combination of virtual and real world, that includes interactivity, very similar to virtual reality. Both technologies are useful when social distancing is forced upon the population.

The implementation in training and education is quite successful due to the immersive and engaging nature of the technology. The main advantage of this technology is the ability to move and interact within a fully 3D space. The users are also able to interact with each other, creating many opportunities to realize various scenarios. The accessibility and quick setup allow for everyday practise. Scenarios are repeatable thus

users can make mistakes and learn from them without facing dire consequences they would be in some cases in real situations.

When training is done virtually there are fewer resources required. Physical simulations vary in price, but generally are more expensive than their virtual counterparts. The reduced cost and option to be set up or used by one person are considerable advantages when social distancing restrictions are imposed. The cost of software is generally a fraction of the price of hardware, but both depend on quality of the product.

Virtual reality saves space. The space VR setup occupies is much smaller than a regular training would require. According to Pottle (2019) a small space of 2 x 2 m is enough for a VR clinical scenario. The entire setup can be done under 5 minutes. With less space occupied, it is possible to make us of the remaining space for other activities. Virtual scenarios should be tested to ensure consistency. VR is improving communication in professional work, mainly in situations where personal meetings are not a viable option. Learning to use this technology proved to be quite beneficial. Training could be implemented into educational program of many institutions, whether pandemic countermeasures are applied or not. The implementation of such technology is not always an easy option since not every institution has the financial resources or willingness to go through with this solution. Virtual and augmented reality are quite effective tools that not only provide entertainment, but also help with education.

The virtual environments are experienced through headsets or helmets equipped with motion sensors. These headsets provide 180-degree field of view, that is a bit less than the human eyes can see, but it is enough for a comfortable experience. Another important part of the experience is sound that comes from a pair of headphones. The entire experience can be enhanced with a pair of hand controllers or even a treadmill. Hand controllers track one's hand gestures and movements, translating them into the application the user is using. VR omnidirectional treadmills allow for free physical movement. Built in inertia systems track users' movement. The movement is converted into data and sent to a computer. The same goes for the data from hand controllers. The user is restricted by a waist brace in order to prevent any kind of unwanted injury.

Framerate is another important aspect of the headsets. In order to not be nauseating or causing headaches, the virtual environments need to be running in at least 60 FPS, but the higher the framerate is the better is the experience.

VR is a remarkable tool for practise of different kinds of medical treatments. The price and adaptability of virtual reality make it usable in vastly different scenarios. Virtual environment in learning in not anything new. As VR has become more advanced and available, it's deployment in the medical field increased.

During COVID-19 restrictions virtual reality can be quite useful, especially when it is not possible to visit certain places or the number of visits is quite limited. It can help in medical staff training, getting students familiar with different treatments and medical environments, while speeding up the entire process. Streamlining the process of training and overcoming restrictions is one of the biggest advantages of the virtual reality technology. Due to movement tracking capabilities of VR headsets medical students are able to experience various scenarios and get familiar with the way they are handled. Additionally, patients can be educated via the use of this technology as well, getting them familiar about certain procedures.

Various techniques of visualisation have been in development since the early 2000s. Many interactions such as picking up objects, pulling or grabbing can be rather faithfully recreated in real-time (Park et al., 2015). Being convenient by providing sufficient training programs helps employees to learn in certain scenarios more than they would in the traditional programs. While pandemic restrictions are limiting the learning possibilities or on-the-job training, is not possible for virtual or augmented reality to help address every rather practical problem with education.

According to Wang et al. (2018) immersive VR and AR have enormous potential to increase students' participation, interaction and motivation. Helping with spatial understanding and visualisation of detailed environments without actually having to visit them personally is the biggest advantage of the technology. Scanning technologies that assist in creating virtual environments such as photogrammetry and point clouds acquired by laser scanners or 3D cameras aid in creating accurate scenes. These methods are cost-efficient and authentical approaches (Wang et al., 2015) serving for portraying scene accurately for training and education. The more accurately the digitalized environments are represented the higher level of awareness about the content of learning the users will grasp. Even during COVID-19 restrictions it is possible to achieve considerably detailed and authentic experiences from utilising these technologies to their full potential.

There are still many opportunities for improvement, but essentially immersive VR and AR combined with their various accessories provide a compelling alternative to the traditional way of learning and education.

8.3 Technology for online education

Educational institutions in developed countries around the world used various means of virtual education during the COVID-19 crisis and its subsequent restrictions. Many countries that are still developing and do not have access to the internet or other necessary complementary technologies, have to rely on traditional methods for education. Numerous institutions were forced to take advantage of available technology and change their education programs.

Adapting to online environments was at times necessary. This eventually resulted in rather fast familiarization with previously underutilised hardware and software. COVID-19 forced institutions and their workers to adapt or learn in order to keep their curriculums working. According to UNESCO (2022), over 1.5 billion students worldwide were affected by COVID-19 restrictions and their impact on education.

One of the main advantages of online learning is the independence to self-study. The benefit of relatively free time might be enjoyable to many individuals. A learning environment that primarily consists of text files, presentations and videos of recoded lectures differs greatly from the traditional education system. Online education can be cost-effective and innovative since large amounts of study material are already digital. Several applications such as Zoom, Microsoft Team, Zoom or Discord help to transform screens into a classroom where teachers can intensely interact with their students (Rehman et al., 2021). Lessons should be as immersive as possible. Other benefits are the elimination of commuting and the removal of social limits. While online learning offers many benefits, it also has downsides. Not all students have access to a reliable internet connection or devices that allow for appropriate online education. Cybersecurity is an important factor in online learning that needs to be taken care of.

There is still no definitive alternative to the traditional way of learning at school. Even if pandemic restrictions affect and change the way schools operate, technologies provide various helpful alternatives, but the effectiveness of online learning is debatable. Online education is a suitable alternative during a pandemic.

For students, it might be difficult to pay attention with many distractions surrounding them. When students are in a classroom the possibility of being distracted is smaller. Both systems have flaws, but the optimal way is the combination of online and face-to-face teaching. Some lessons can be presented online, but certain aspects of face-to-face teaching cannot be replicated online.

CONCLUSION

This thesis focuses on social distancing technologies, examining their advantages, disadvantages and characteristics. A great number of modern technologies provide significant benefits in everyday lives during quarantines and various pandemic restrictions. Every technology investigated and described in this thesis has helped people cope with the pandemic. Certain technologies such as drones or artificial intelligence still require more testing or development in order to be effective. Thus far, these technologies have limitations that prevent them from reaching their full potential. The benefits they provide are already notable and will increase as the technologies develop.

The rest of the investigated technologies have already proven quite beneficial. The most desirable results are accomplished when multiple technologies are deployed simultaneously, cooperating together. For example, using a self-checkout kiosk and paying with a digital wallet. We live in a society that relies on technology more often than not. Technology surrounds most people in all of their activities. If people let technology help them and utilize it properly, it can make life very easy, but everything has its limits. People should not rely too heavily on it because if they do, it can create addiction or numerous psychological problems.

The worldwide pandemic significantly accelerated this dependence and deployment of technologies. COVID-19 restrictions require less human contact in order to prevent the spread of the virus. Removing workers from unnecessary positions is one of the most prominent advantages of these technologies. Many processes can be automated or simplified without any major setbacks. A number of the changes that the pandemic caused are here to stay. People were forced to familiarize themselves with tools never used before or live under inconvenient restrictions.

When more people work or study from home, the lower the chance of a coronavirus spread. Technologies enable many alternative solutions to established workflows and create new opportunities that speed up or streamline existing systems and processes. When social distancing is necessary due to a pandemic and people being forced to be quarantined, current technologies allow people to perform most of their everyday tasks without any major impediments. Certain tasks or activities cannot be replaced, but technologies are slowly improving and becoming more immersive every day. Technologies help during social distancing protective measures when used sensibly.

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LIST OF ABBREVIATIONS

Abbreviations:

UAV	Unmanned Aerial Vehicle
GPS	Global Positioning System
GNSS	Global Navigation Satellite System
RSSI	Received Signal Strength Indicator
JCE	Journal of Clinical Epidemiology
UK	The United Kingdom of Great Britain and Northern Ireland
AI	Artificial intelligence
B2B	Business-to-business
GPU	Graphics processing unit
TOF	Time-of-Flight
FPS	Frames per second
VR	Virtual reality
AR	Augmented reality